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RESEARCH PAPER

Shading System on Sandalwood Seedlings in Timor, East Nusa Tenggara, Indonesia

I. Komang Surata · Tigor Butarbutar

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Abstract Mortality rates of seedlings of sandalwood (*Santalum album* L.) of more than 40% have been observed in cool wet upland areas in various countries. Mortalities are caused by low sunlight intensity and high soil humidity after watering, when seedlings are growing in modern shade houses (paranet roof with 50% solar intensity) in relatively high rainfall upland areas. To cope with this problem, it is proposed to use conventional sheltering construction with roof material modification as one of the alternatives to implemented to intensity solar radiation and reduce soil humidity. This method was proposed to increase the growth rate and reduce fungal decay in seedlings. The study observed the effect of various roof materials used with conventional nursery construction on growth of sandalwood seedlings. A randomized block design was adopted, with treatments consisting of roof material types, including coconut leaf (*Cocus nucifera*), imperata grass (*Imperata cylindrica*), transparent plastic, plastic roof (laserlaip), and paranet. A modern shade house was used as a control variable. The experimental design included three blocks and each block consisted of 50 replications. Conventional sheltering devices were found to be superior to other devices for 8-month-old sandalwood seedling. The conventional seedling sheltering device from corrugated plastic roof (laserlaip) resulted the greatest growth in height and diameter and greatest survival percentage of sandalwood seedlings. The highest to lowest rank of growth in order were plastic roof, paranet, transparent plastic, coconut leaf, imperata grass, and shade house, with survival percentage in each sheltering device of 62.12%, 53.55%, 41.81%, 40.82%, 38.51%, and 12.82%, respectively. Waving plastic roof resulted in highest seedling growth than other treatment because it is protected from rain water (waterlogging) and will raise the temperature and the intensity of sunlight received.

I. K. Surata · T. Butarbutar (✉)
Forest Research Institute, Jl. Untung Surapati No. 7 (Belakang), P.O. Box 69, Kupang, Indonesia
e-mail: tigtars@yahoo.co.id

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Introduction

The genus *Santalum* embraces 15 species and 14 varieties, and one extinct species of trees and shrubs distributed naturally from India, Indonesia, and Pacific Islands (Applegate et al. 1990). One species growing naturally in East Nusa Tenggara (NTT) islands is known as sandalwood (*Santalum album* L.). Sandalwood is highly priced for its fragrant heartwood, used mainly for incense and oil production. In recent years the population of sandalwood in its natural habitat has decreased because of over-exploitation, including illegal logging. Production of sandalwood fell from 600 tons in 1997 to 100 tons in 1999 (Darmokusumo 2001). The remaining stock cannot meet national and international demand for sandalwood and oil in a sustainable manner. The establishment of sandalwood plantations is one way to increase the supply of sandalwood to meet demand for the wood and oil.

Since 1998 the regional government has attempted to develop sandalwood plantations in the forest area, but due to the lack of silvicultural techniques and lack of tending in the field, most plantations have been unsuccessful. Also, there has been a scarcity of seedlings, because special nursery techniques are required for this species. The new strategy is to develop the small-scale sandalwood plantation not only in forest areas but also on the community and private land. To ensure seedling supply, it is necessary to advise farmers on how to produce seedlings in the traditional way.

To ensure the success of sandalwood plantations, high quality seedlings are needed. Surata (1994) specified that desirable quality seedlings have a brownish woody stem, 25–40 cm height, and 0.30–0.50 cm stem diameter by 8 months of age. The quality of seedlings produced is greatly affected by micro-climatic factors including intensity of sunlight, air temperature, air humidity, and soil humidity. Design of the shading system that is optimal for the growth of sandalwood seedlings involves considerations of the kind of nursery building, and particularly the choice of roofing material.

There are many reported observations on the effect of shade on sandalwood (e.g., Hutchine in Barret, 1985; Rain in Hamilton et al. 1990; Kharisma and Suriamihardja 1991; Barett and Fox 1995; Surata 2006). However, none of these report investigated the effect of the amount of shade in the nursery. More recent observations indicate that stem diameter growth of *Quercus petraea* on farms is often reduced in tree shelters from natural shade produced by standing trees (Mayhead and Boothman 1997). After trees emerged from the top of the shelter during the first growing season, the negative impact of tree shelters on tree diameter growth was still significant while the negative impact on the tree height was no longer apparent.

Surata and Idris (2001) observed that mortality among sandalwood seedlings in cold areas and highland areas with high rainfall has been as high as 60%. The seedling deaths are due to the low sunlight intensity, low temperature, excess water during the rainy season, and the nursery being continually damp. Hutchine (1884) observed that the mortality rate of sandalwood seedlings is high in nurseries in high-rainfall regions, because the seedlings cannot tolerate waterlogging in the

Table 1 Monthly rainfall recorded during the nursery shading trial

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean rainfall (mm)	564	269	462	423	13	23	0	0	0	45.1	207	342.6
Number of rainy days	22	14	20	14	2	4	0	0	0	3	8	11

Source: Climatology station at SoE Regency (2004)

germination medium. When seedlings are too wet, they become vulnerable to leaf diseases with leaves turning brown and eventually falling, with the seedlings having little chance of survival.

Many kinds of nursery buildings have been developed recently for shading system, one being the modern nursery (shade house), which has a paranet roof of 50% intensity, and another the conventional nursery,[1] the roof of which is made of locally available materials (coconut leaves and imperata grass leaves). Different nursery buildings will produce seedlings of different quality at the same age. Development of improved shading systems is important for ensuring successful production of sandalwood seedlings. If the humidity of soil and air is extreme then normally the *Fusarium oxyporus* and *Aspergillus flavus* cause mortality of seedlings, as noted by Hamzah (1976).

The traditional shading system with coconut leaves and imperata grass leaves for the nursery roof is conventionally used for large-scale seedling production for plantation forestry in Timor. It has been proved efficient in fostering sandalwood seedlings, considering that these structures are less costly (the materials being easily found locally) and can be constructed near the village area for smallholder sandalwood plantation. However, the conventional nursery building has to be modified by use of a more appropriate roofing material, one that can maximize light at a temperature that is of optimal benefit for sandalwood seedlings, so as to reduce the mortality rate. One way to do this is to choose nursery shade roofing which is appropriate for local conditions. A conventional nursery shade roof can be constructed cheaply of local materials, those available in the prospective nursery location such as coconut (*Cocus nucifera*) leaves and imperata grass (*Imperata cylindrica*) leaves. The present study was designed to determine the effects of various shading systems of conventional nurseries on the growth of sandalwood seedlings.

Materials and Methods

The research site was the Forestry Research Station at Buat, South Central Timor (TTS) Regency, East Nusa Tenggara (NTT) Province. The research site is at an elevation of 850 masl, with Grumusol soil (Pusat Penelitian Tanah dan Agroklimat 1993), the average of monthly maximum air temperature ranges from 27 to 31°C, and average rainfall of 2,328 mm/year. Table 1 reports the monthly rainfall recorded during the trial.

[1] The conventional nursery structure is of poles rather than steel or bricks, and can be constructed by communities and smallholders.

Nursery preparation took place from November 2003, with the shading trials carried out from January to December 2004. Seed of *S. album* was collected during March 2003 from a natural stand at Buat. To soften the exocarp depulped and dried seed was soaked for 24 h in ordinary water. Three sandalwood seeds were sown in each 15 cm × 20 cm plastic bag filled with germination medium consisting of a 4:1 mixture of topsoil and sand. The primary host (*Alternantera* spp.) was planted in the polybag alongside the sandalwood seedling to supply water, N, P, and K to the sandalwood seedlings. One seedling was retained per polybag, and the crown of the host plant was pruned to prevent shading the seedling.

The sandalwood seedlings were placed on the floor in a conventional nursery structure, the bedding measuring 1 m × 5 m, the front roof post 1.2 m in height and the back post 1 m. The nursery structure faced the east. Some seedlings were placed in a seedling bed measuring 6 m × 8 m, with a height of 2 m and having a paranet roof with shading intensity of 50%.

The experiment followed a randomized block design with treatments based on the kinds of roof materials for shading the conventional nursery as follows: coconut leaves, imperata grass leaves, transparent plastic (*mikel* plastic), corrugated plastic (*laserlife*), and *paranet*, and with a permanent nursery (*shade house*) for as a control. Each treatment consists of three repetitions or blocks, with each block containing 50 seedlings in polybags. To ascertain the effect of the treatment, monthly measurements are made of the height, diameter of root collar, and the percentage of surviving plants up to the age of 8 months.

The particularly wet season when the shading experiment was conducted caused the germination medium to become soaked in the treatment of having paranet, coconut leaves, and cogon grass for roofing and in the shade house.

Aside from measurement of plant growth, data on micro-climatic factors were recorded, including atmospheric temperature, humidity and intensity of solar radiation, for each treatment plot. These observations are made at 10 am to 12 noon, that is, while the sky is clear. Rainfall was recorded during the trial.

At the termination of experiment, randomly selected seedlings from each replicate were carefully uprooted without damaging the root system and washed in running tap water. The seedlings were cut at the root collar and the roots and tops dried separately at 60°C in paper bags in an oven for biomass estimation. The dry shoots and roots were weighted using a top pan electronic balance. The top/root dry weight ratio was calculated for each plant.

Following Dickson et al. (1960), a quality index (QI) was calculated as:

$$QI = \frac{s}{(h/d) + (t/r)}$$

where s = seedling dry weight (grams); h = height (cm), d = diameter (cm), t/r = top/root ratio.

An analysis of variance (ANOVA) was performed using *Statistical Product and Service Solution*s for Windows (Santoso 2000). The effects of treatment were further tested by the 0.05% honestly significant difference test (described by Steel and Torrie 1980). Treatments were ranked by an Ordinate Number Analysis (Goodall 1954, reported in Wilde et al. 1979).

Results of the Shading Trial

The results of a series ANOVA of seedling growth (height and diameter), survival rate, and QI of the sandalwood seedlings with regard to the nursery shading roof at the age of 8 months are reported in Table 2. Each of the performance variables is found to differ significantly between treatments. Multiple comparisons in terms of the honest significant difference indicate differences between treatments (Table 3) reveal that use of the conventional nursery structure, with the roof made of coconut leaves, imperata grass leaves, transparent plastic, corrugated plastic or paranet, leads to greater plant height, diameter, survival, and QI of surviving sandalwood seedlings than using the modern nursery structure (shade house).

Use of corrugated plastic roofing on the conventional nursery structure has proved best for increasing stem diameter, survival, and QI of seedlings compared with using coconut leaves, imperata grass leaves, or paranet on the same type of conventional nursery structure or using the nursery structure called the shade house. According to the ordinate number analysis, the best-growth ranking order from highest to lowest (Table 3) The order of treatments from the highest to the lowest in terms of the growth parameter of height are, respectively, from the treatment of corrugated plastic roofing through transparent plastic, coconut leaves, paranet, imperata grass and shade house. For survival percentage, the order is from the treatment of corrugated plastic roofing through paranet, coconut leaves, imperata grass, transparent plastic, and shade house.

The survival rates of sandalwood seedlings are 62.12%, 53.55%, 41.81%, 40.82%, 38.51%, and 12.82% for the treatment of corrugated plastic roofing through transparent plastic, coconut leaves, paranet, imperata grass and shade house. This is

Table 2 Analysis of variance for height, diameter, and survival at age 8 months

Parameter	Source of variance	df	MS	F	Significance
Height	Treatment	5	659,250.94	19,813	0.000*
	Block	2	45,780.49	1.376	0.253
	Error	1,070	33,273.02		
	Total	1,077			
Diameter	Treatment	5	13,347.41	18.73	0.000*
	Block	2	524.26	0.722	0.486
	Error	1,070	726.45		
	Total	1,077			
Survival	Treatment	5	6,655,842.09	48.986	0.000*
	Block	2	265,530.89	1.954	0.192
	Error	10	13,5871.69		
	Total	17			
Quality index	Treatment	5	10,347.41	11.73	0.000*
	Block	2	324.26	0.522	0.095
	Error	10	426.45		
	Total	17			

* Significant at the 1% level

Table 3 Average of height, diameter, and growth grade of sandalwood seedling by roof shading treatment at age 8 months[a]

Treatment	Height (cm)	Diameter (cm)	Survival rate (%)	Quality index	Grade
Corrugated plastic	40.23 d	0.58 c	62.12 d	0.32 c	1
Paranet	34.36 b	0.53 b	53.55 b	0.27 b	2
Transparent plastic	38.77 cd	0.52 b	38.51 c	0.23 b	3
Coconut leaves	37.07 bc	0.51 b	41.81 a	0.19 a	4
Imperata grass leaves	28.80 a	0.37 a	40.82 ac	0.17 ac	5
Shade house	25.58 e	0.34 e	12.82 e	0.12e	6

[a] Mean values with the same letter do not differ significantly at the 5% level

Table 4 Average of air temperature, solar intensity and air humidity under each shading roof treatment at 8 months old

Number	Shading treatment	Mean air temperature (°C)	Mean solar intensity (lux)	Mean air humidity (%)
1	Corrugated plastic	31.8	1.800	86.8
2	Transparent plastic	30.1	1.700	82.9
3	Paranet	29.1	1.600	80.9
4	Coconut leaves	27.3	1.400	70.6
5	Imperata grass leaves	27.1	1.500	62.1
6	Shade house	26.3	1.300	71.0

due to the difference in degree of shading of the roof material; the more shading the higher the mortality rate.

The microclimate variables of mean air temperature, solar radiation intensity and air humidity for the shading roof treatments after 8 months were relatively higher than for the traditional shade house (Table 4). The treatments ranked from the highest to the lowest for these microclimate parameters are respectively the treatment of corrugated plastic roofing through transparent plastic, paranet, coconut leaves, cogon (imperata) grass and shade house.

An improved microclimate in the rainy season makes it possible to accelerate drying of the germination medium after splashing or dropping of excess water might occur on the nursery floor. The most favorable values for atmospheric temperature, sunlight intensity and humidity—for the treatment of using corrugated plastic roofing—are, respectively 31.8°C, 1.800 lux and 86.8%.

Discussion

Seedling growth with the use of the conventional nursery structure having a roof for shading made of corrugated plastic results in the greatest height and stem diameter and the greatest survival rate. This is due to the fact that the conventional nursery

structure with corrugated plastic roofing is able to protect the sandalwood seedlings from excess of water in the rainy season and is additionally able to increase sunlight intensity, air temperature, and air humidity. It should be recognized that during the trial the seedlings were subjected to particularly high rainfall was carried out in a year with above average rainfall and a high number of rain days from November 2003 to April 2004.

To accelerate drying in the case of excess water from rainfall or from sprinkling, a shelter for sandalwood seedlings such as corrugated plastic is needed. A nursery structure that is not rainproof results in stagnant water pools which cause high seedling mortality.

Shading systems are widely used to protect seedling from reduced photosynthetic activity due to the lower solar radiation, lower daytime temperature, and the air saturated with water vapour. As a result of shading, the microclimate for seedlings is altered, which has an impact on transpiration (Bergez and Dupraz 2000). However, the other observations have indicated that stem diameter growth is often reduced in tree shelters (Tuley 1983). It was also shown that trees emerged from the top at the shelter during the first growing season, the negative impact of tree shelters on tree diameter growth was still significant after out-planting, while the height advantage had vanished.

Shading of sandalwood plants is necessary at the early nursery stage (up to the time when the seeds germinate), after which seedlings need increasing amounts of sunlight. Too much shade not only hampers seedling growth but also increases seedling mortality (Surata and Idris 2001). Shading of the sandalwood plants is only necessary for protecting the seedlings from intense sunlight. A limitation in this research is the lack of a plan to observe the intensity of sunlight so as to determine the optimal amount needed for sandalwood growth, and thus the optimal intensity of sunlight for the growth of sandalwood seedlings has not been ascertained.

Conclusion

It is critical in sandalwood nurseries to select the best nursery roof material to produce higher quality seedlings. The ranking of sandalwood seedling quality from highest to lowest are, respectively, obtained in the treatments using corrugated plastic roofing (laserlife), paranet, transparent plastic (*plastik mikel*), coconut leaves, imperata grass roofing, and a shade house, the respective survival percentages being 62.1%, 53.6%, 41.8%, 40.8%, 38.5% and 12.8%, and the QI 0.32, 0.27, 0.23, 0.19, 0.17 and 0.12.

The shading system construction using corrugated plastic roofing (laserlife) proved superior to alternative roofing materials for production of high quality sandalwood seedlings, because this shading system protects the sandalwood seedlings from rain water and raises the temperature and the intensity of sunlight to promote the greatest *S. album* growth.

Training of nursery owners and managers about the various kinds of nursery roofing so that they are able to understand the most advantageous and optimal kind

to use on sandalwood nurseries with a view to reduce seedling mortality and increasing growth rates.

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